Microsurgical Clipping of Intracranial Aneurysms Following Unsuccessful Endovascular Treatment

Analysis of Ten cases

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Summary

The purpose of the current study was to examine the reasons for failed endovascular aneurysm coiling and to determine the outcome of immediate microsurgical clipping. From July 2006 to July 2008, 198 patients underwent endovascular coiling at our institute; among them, ten cases were unsuccessful. All of the patients were diagnosed with intracranial aneurysms (ICAs) by cranial computed tomography angiography (CTA), and all underwent endovascular treatment without digital subtraction angiography (DSA). When endovascular coiling failed, the patients were immediately transferred to the operating room for microsurgical clipping under the same anesthetic. The ten patients were divided into three groups based on the cause of endovascular failure and associated clinical features. The clinical follow-up period was between 6-12 months, and all 10 patients had good outcomes following the surgery. Taken together, the results of this study suggest that immediate microsurgical clipping after failed endovascular coiling is efficient and may provide improved outcomes by preventing rebleeding.

Introduction

In the past decade, there have been dramatic advances in the development of new techniques and devices, such as stents, for the endovascular treatment of intracranial aneurysms. Today, endovascular coiling is considered a minimally invasive treatment option with good clinical results and adequate protection from rebleeding [1]. However, due to the growing number of intracranial aneurysms treated with endovascular coiling, clinicians are now faced with a group of patients who have undergone endovascular treatment that resulted in failed endovascular coiling [2]. After endovascular coiling fails, microsurgical clipping of the aneurysm under the same anesthetic may be a good option. However, relatively little is known regarding the causes, management and outcomes of failed endovascular treatment. In the current study, we retrospectively reviewed ten cases in which patients had undergone failed endovascular coiling followed by immediate microsurgical clipping to gain further insight into this approach.

Materials and Methods

Patients

Ten patients, including five males and five females, whose ages ranged from 36 to 74 years (average age: 54 years), were selected to undergo endovascular therapy. All patients had a subarachnoid hemorrhage (SAH). Treatment by microsurgical clipping occurred between one and five days after the SAH diagnosis. The presence of the SAH was confirmed by cranial computed tomography angiography (CTA) after SAH. Among the ten aneurysms, five were located in the anterior communicating artery (AcoA), four were located in the posterior communicating artery (PcoA), and one was an internal carotid artery bifurcation (ICA-bif); four of the aneurysms had wide necks (neck/dome > 0.5). Hunt and Hess grading showed that five cases were class I, three cases were class II, and two cases were class III. The diameter of the aneurysm bodies ranged from 3.0 to 4.5 mm (average diameter: 3.72 mm). Patient data are summarized in Table 1.

Preoperative Management

The presence of an intracranial aneurysm in all ten patients was confirmed by CTA or DSA after SAH. Preoperative management included intravenous administration of nimopidine (Bayer, Germany) at a rate of 4 mL/h for one to three days before surgery to prevent vasospasm. The four patients with wide-necked aneurysms received clopidogrel (75 mg) and enteric-coated aspirin (100 mg) orally for three days before the surgery (one dose per day for both drugs).

Endovascular Procedure

All endovascular procedures were performed with the patient under general endotracheal anesthesia. Femoral access was obtained by means of a single-wall puncture with a 6F vascular sheath. Three-dimensional digital subtraction angiography (3D-DSA) was performed before surgery. The anatomical relationship between the aneurysm and parent vessels was evaluated by 3D reconstruction of the aneurysms. Subsequently, a suitable operating angle was selected for endovascular embolization. Embolization was performed with electrically detachable coils or hydrocoils (including two- and three-dimensional (3D) coils with various degrees of flexibility). Among the patients with wide-necked aneurysms, one was treated with stent assistance and one was treated with balloon assistance. Patients were transferred to the operating room under general anesthesia to perform microsurgical clipping immediately after the unsuccessful endovascular coiling.

Microsurgical Clipping Procedure

A pteryonal approach was selected for all patients. After the fissure was opened widely to expose the parent artery, the clot was carefully dissected away from the aneurysm neck, and the neck was clipped.

The patency of the parent, branching and perforating arteries and documentation of clip occlusion of the aneurysm were assessed by near infrared indocyanine green video angiography (ICGA) integrated onto an operative Pentero neurosurgical microscope (Carl Zeiss, Oberkochen Germany).

Table 1 **Clinical data of the patients.**

	Patient No.	Hunt and Hess Grade	Timing of Coiling (d)	Sex/Age (yr)	Aneurysm Location	Aneurysm Size (mm)	Wide Neck	GOS
Group I	1	I	5	M/64	PcoA	3.5	N	5
	2	II	4	F/48	AcoA	4.0	Y	5
	3	III	4	M/53	AcoA	3.0	N	5
Group II	1	I	2	F/55	PcoA	4.2	N	5
	2	II	3	F/52	ICA-bif	4.5	N	5
	3	I	1	M/74	AcoA	3.6	N	4
	4	I	3	M/38	AcoA	3.6	Y	5
Group III	1	III	1	F/66	PcoA	3.2	Y	5
	2	III	3	M/54	AcoA	3.8	N	5
	3	I	2	F/36	PcoA	3.8	Y	5

AcoA: anterior cerebral communicating artery, PcoA: posterior cerebral communicating artery, MCA: middle cerebral artery ICA-bif: internal carotid artery bifurcation

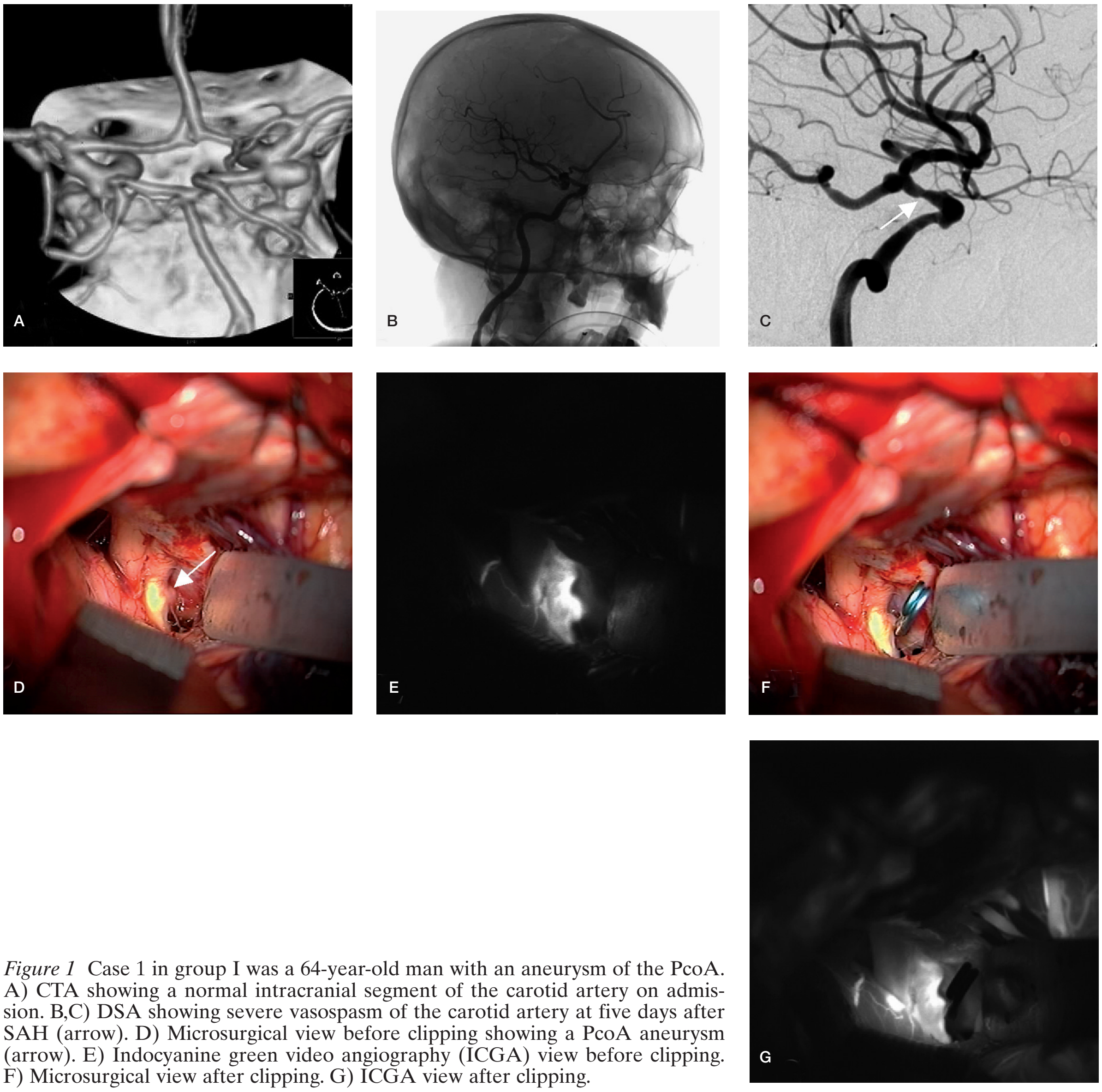

Figure 1 Case 1 in group I was a 64-year-old man with an aneurysm of the PcoA. A) CTA showing a normal intracranial segment of the carotid artery on admission. B,C) DSA showing severe vasospasm of the carotid artery at five days after SAH (arrow). D) Microsurgical view before clipping showing a PcoA aneurysm (arrow). E) Indocyanine green video angiography (ICGA) view before clipping. F) Microsurgical view after clipping. G) ICGA view after clipping.

Postoperative Management

Lumbar cerebrospinal fluid (CSF) was drained for at least seven consecutive days after surgery. Hemorrhagic CSF was drained using an external ventricular drainage system to reduce intracranial pressure and to improve cerebral vasospasm. Changes in intracranial pressure were monitored closely based on the liquid height of the external ventricular drainage tube to maintain an intracranial pressure below 200 mm H_2O[3]. Nimopidine (4 mL/h) was administered continuously for three weeks after surgery to prevent or alleviate vasospasm. For patients with significantly increased intracranial pressure, a combination of mannitol, furosemide and albumin was administered.

Classification by Causes of Unsuccessful Guglielmi Detachable Coil Embolization (GDC)

Unsuccessful GDC was categorized as follows. Group I: DSA demonstrated severe parent artery vasospasm so that the catheters and delivery systems could not cross the stenosed area. Group II: the carotid, supra-aortic vessels, and/or femoral artery had a tortuous or abnor-

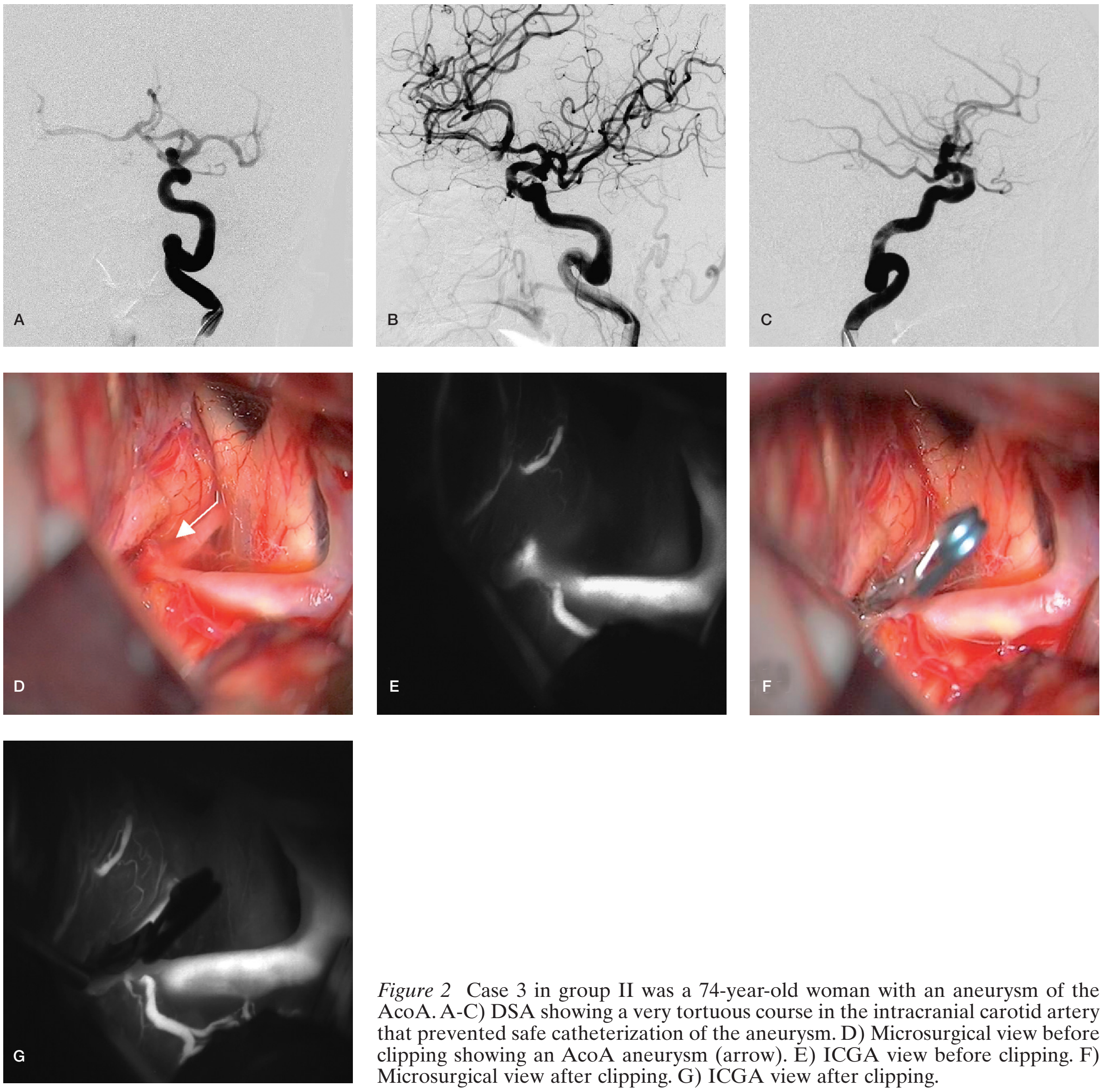

Figure 2 Case 3 in group II was a 74-year-old woman with an aneurysm of the AcoA. A-C) DSA showing a very tortuous course in the intracranial carotid artery that prevented safe catheterization of the aneurysm. D) Microsurgical view before clipping showing an AcoA aneurysm (arrow). E) ICGA view before clipping. F) Microsurgical view after clipping. G) ICGA view after clipping.

mal course that prevented safe catheterization of the aneurysm with the microcatheter. Group III: during embolization, detached coils herniated into the parent artery from the aneurysm sac; this group included the patients with wide-necked aneurysms who underwent unsuccessful stent/balloon-assisted coil embolization.

Results

The causes of unsuccessful GDC were analyzed and described as follows.

Group I: CTA in all cases showed that intracranial vessels were normal on admission, but the aneurysms could not be treated successfully using the endovascular approach five days (case 1) or four days (cases 2 and 3) after SAH, because the internal carotid artery (case 1) or the A1 segment of the ACoA (case 2 and case 3) had severe vasospasm. As a result, the delivery systems of the coils could not cross the spastic vessels.

Group II: Case 1 was diagnosed as a PcoA aneurysm on CTA, but DSA revealed an abnormal aortic arch that coursed from left to

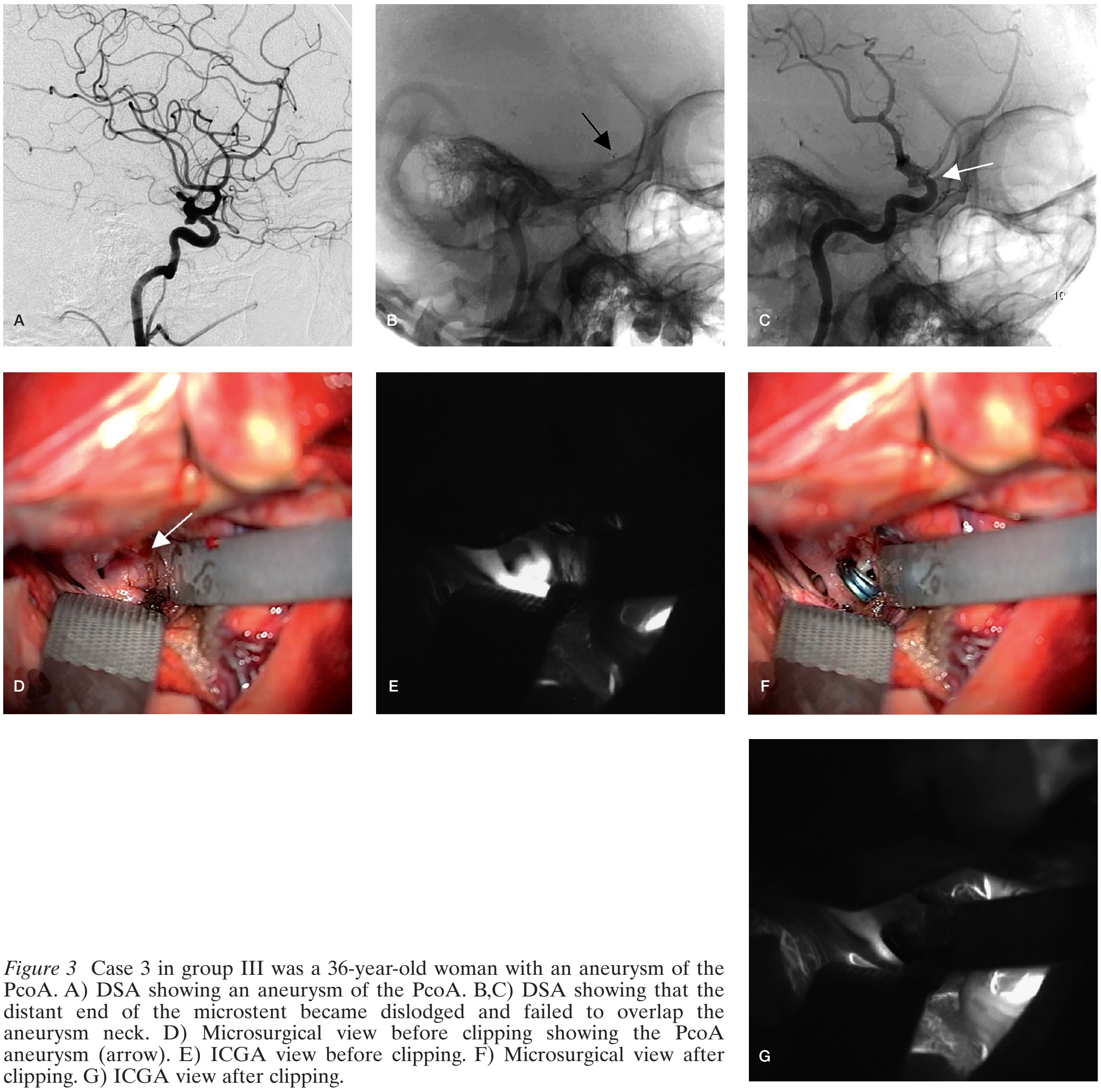

Figure 3 Case 3 in group III was a 36-year-old woman with an aneurysm of the PcoA. A) DSA showing an aneurysm of the PcoA. B,C) DSA showing that the distant end of the microstent became dislodged and failed to overlap the aneurysm neck. D) Microsurgical view before clipping showing the PcoA aneurysm (arrow). E) ICGA view before clipping. F) Microsurgical view after clipping. G) ICGA view after clipping.

right. Because of the complex anatomical structure around the aortic arch, an envoy guiding catheter could not be placed into the carotid artery. Cases 2 and 3 had very tortuous courses in the intracranial carotid artery, which prevented safe catheterization of the aneurysm. In case 4, there was a wide-necked aneurysm in the AcoA that required balloon assistance. However, the balloon catheter could not cross the intracranial arteries due to tortuosity.

Group III: In cases 1 and 2, when a detachable coil was placed in the aneurysm sac through a microcatheter positioned in the aneurysm sac, a coil loop herniated into the parent artery. In case 3, repair was attempted using a neuroform stent due to the wide neck of the aneurysm. During the procedure, however, the distal end of the microstent became dislodged and failed to overlap the aneurysm neck.

Outcomes: The intraoperative and postoperative courses of all patients were uneventful. At the six to 12 month follow-up visit all of the patients were doing well.

Discussion

Endovascular treatment is increasingly preferred for intracranial aneurysm treatment [1]. First reported by Guglielmi in 1991, endovascular treatment of intracranial aneurysms has been widely utilized due to low levels of damage and quick recovery [4]. The International Subarachnoid Aneurysm Trial (ISAT), a large randomized study that compared the outcomes of endovascular treatment and surgical clipping, showed that outcomes associated with endovascular treatment were significantly better than outcomes associated with surgical clipping: the patients who underwent endovascular treatment survived at least seven years. These conclusions led to the wider use of endovascular approaches to treat ICAs [1].

Endovascular treatment of ICAs is limited in clinical practice in China due to high costs. The majority of Chinese patients accept CTA examination to confirm an SAH diagnosis, followed by direct endovascular therapy. The patients typically do not undergo further DSA examination [5]. This procedure is similar to that used in SAH patients who immediately underwent endovascular therapy following ICA diagnosis by DSA examination. The advantages of the current procedure include reduced costs and a shorter therapy period. However, because knowledge of the anatomical structure of the artery and intracranial vessels was limited prior to the endovascular operation, the frequency of failure was higher.

Despite its widespread use, endovascular treatment is not without limitations, and not all endovascular coiling treatments are successful. There are many reasons for unsuccessful aneurysm coiling. Shanno et Al [2] reported that the most common reason for an unsuccessful procedure was an inability to catheterize the aneurysm due to the shape of the aneurysm or severe vasospasm and vascular tortuosity. In the current study, the reasons for unsuccessful endovascular treatment were similar to the previous report, but Shanno et Al also noted other serious adverse events, including significant thromboembolic and hemorrhagic complications that contributed significantly to instances of morbidity and mortality. In the current study, cerebral blood flow was not disturbed when embolization was unsuccessful, and the clinical features and outcomes did not include the serious complications reported previously [6]. Taken together, the results of the current study suggest that transfer of patients under general anesthesia to the operating room to perform microsurgical clipping immediately after unsuccessful GDC may be beneficial. This efficient approach may dramatically decrease costs while providing improved outcomes by preventing rebleeding.

In group I, unsuccessful GDC was from delayed cerebral vasospasm, which usually occurs at the third day after SAH, peaks between four an 12 days, and remains high for more than three weeks [7]. In this group, the aneurysm was diagnosed based on CTA examination, even though obvious intracranial vasospasm was not detected by CTA. However, there was a delay of more than four to five days between diagnosis and GDC treatment. The two primary causes of failed endovascular operations, which were determined when DSA showed vasospasm on parent artery, included: 1) microcatheters and microguidewires were inaccessible, or B) passage may influence distal region of blood flow dynamics. Cerebral vasospasm in this group was asymptomatic, the patients did not exhibit neurological deficits, and DSA demonstrated adequate filling of distal vessels. It was therefore feasible to perform a craniotomy and aneurysmal clipping immediately. Surgical clipping was performed immediately under the same anesthesia to avoid potential damage associated with rebleeding and repeat anesthesia with a second surgery. Evacuation of blood clots from the subarachnoid cavity and cisterns during surgery is believed to reduce the incidence of vasospasm [9]. Currently, craniotomy and microsurgical clipping is an option in patients that do not exhibit symptoms associated with neurological deficits. Three patients in group I met these conditions, and they all accepted craniotomy and clipping with very good outcomes.

In group II, unsuccessful GDC was due to tortuous vessels or artery dysphasia during microcatheter navigation. The failure rate under these conditions is between 2.3 and 16.1%, according to a previously published study [10]. When tortuous vessels are present, manipulation of microcatheters and microguidewires is difficult, frequently leading to failed aneurysm targeting. Even if navigation is successful, decreased stability may impede successful embolization [11,12]. In group II, case 1 had a right aortic arch, which is a rare condition, comprising approximately 0.1% of the cases reported in several studies. It is often associated with direct origin of carotid arteries from the arch [13]. Because of the unusual anatomy in this case, successful catheterization of the aneurysm was not possible. For the cases in group II, surgical clipping was immediately performed after failed embolization and the outcomes were very good. This is due to the fact that even if the microcatheter and/or microguidewire failed to navigate into the aneurysm cavity, it did not adversely affect the parent artery.

In group III, unsuccessful GDC and failed coil embolization were caused by coil protrusion into the parent artery. In the two wide-neck aneurysms, the coils could not be detached due to the wide neck of the aneurysm. In the other aneurysms, coil protrusion was caused by tension in the aneurysm cavity that made the coil undetachable [16]. Further manipulation of both the microcatheter and the microguidewire were ceased because longer operations may induce vasospasm. Timely withdrawal of the coil is important to avoid damage to the coil structure and overstretching. Failure to withdraw the coil may lead to in situ or ectopic embolism of the parent artery. An alternative option is to use remodeling techniques, such as balloons or stents. In the current study, we implanted neuroform stents in case 3, but it shifted when detached. In the end, the sac failed to be occluded. Although coil embolization was unsuccessful in three of the cases in group II, endovascular manipulation did not damage the cerebral vessels, and DSA showed that the distal regions of the aneurysms remained clear. Surgical clipping was undertaken under the same authorization. If the patients were treated with anti-coagulation drugs prior to the operation, higher postembolization hemorrhage could occur in the operation fields during clipping. Therefore, this procedure required precise control of hemostasis during surgical clipping.

Conclusions

In cases of failed endovascular coiling, additional surgery and anesthetic are unfavorable due to the increased risk of complications. If the distal arteries appear clear, immediate microsurgical clipping offers the possibility of a good outcome. Taken together, the results of the current study suggest that immediate microsurgical clipping after failed endovascular coiling is efficient and may provide improved outcomes.

This approach avoids increased operative risks, prevents possible complications associated with additional surgery, reduces rebleeding and prevents repeat anesthetic.

The prerequisites to this procedure include: 1) the patient must be in good status, 2) the patient must not exhibit symptoms associated with a loss of nerve function; and 3) the influence of endovascular manipulation on cerebral vessels and blood flow dynamics must be relatively minor.

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